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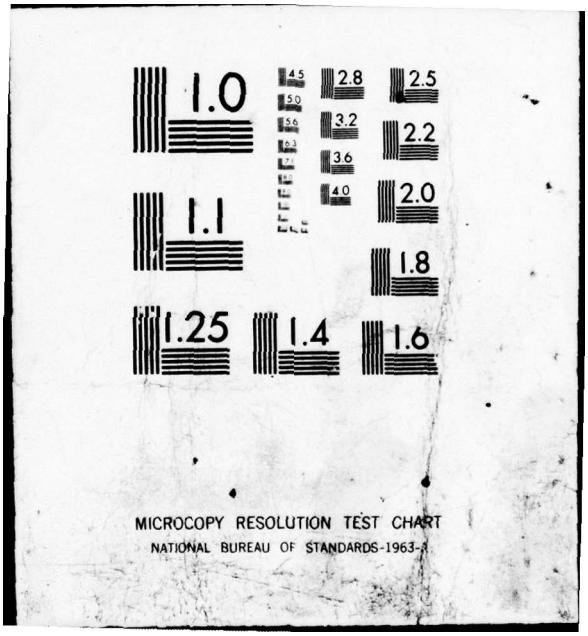
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Cultural fish species in China, such as the grass carp, white bighead, striped bighead, black Chinese roach, and Cirrhina molitorella breed only in flowing water in rivers. After fertilization, the eggs drift downstream gradually developing along the way. Carp and goldfish spawn in either flowing or still water, but the eggs adhere to vegetation until hatched.

Black Chinese roach and striped bighead spawning grounds are distributed in the Yangtze, Pearl and Hwau Rivers, but are not found in northern or

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central China. In addition to the above rivers, grass carp and white bighead spawning grounds are also found in Chekiang and Manchuria. Chirrhina molitorella spawning grounds are confined to southern China. Goldfish and carp can breed almost anywhere.

One survey conducted indicates that there are certain general water conditions common to many spawning grounds: (1) range of water temperature, 20-30C (lowest, 18.3C); (2) range of water velocity, 0.69-2.26 m/sec (lowest, 0.67 m/sec); (3) sudden water level rise, continuing for 12 hrs., or as long as 10 days, where a big rise may reach 0/75-1m in 12 hrs., or a small rise may reach 1-1.3m in 3-5 days; (4) sand and gravel bottom; (5) turbid sandy water; (6) spawning grounds often situated below confluence of two rivers; (7) spawning often occurs after a downpour or freshet.

These general water conditions along with the locality and climate can affect spawning activity, time and period; fish size and age composition; sexual differentiation, cycles, and composition; fecundity; and egg hatching.

Chapter 7

# NATURAL BREEDING

## Natural Spawning Grounds of Cultured Fish Species in China

The grass carp, black Chine roach, white bighead, striped bighead, and Cirrhina molitorella breed only in flowing water in the rivers. After fertilization, the eggs drift downstream with the current and gradually develop on their way down. With the carp and goldfish, the condition is entirely different. They can spawn in either flowing or still water, but the eggs adhere to vegetation until hatching.

The spawning grounds of black Chine roach and striped bighead are distributed in the valleys of Yangtze River, Pearl River, and Hwau River. They are not found in northern or central China. The spawning grounds of grass carp and white bighead are more widely distributed. Aside from the above rivers, they are also found in Chekiang and Manchuria. The spawning grounds of Parabramis pekinensis are also very widely distributed. Cirrhina molitorella is closer to a tropical species; its spawning grounds are confined to southern China. The carp and golfish can breed practically everywhere.

## Natural Conditions of the Main Spawning Grounds

1. Spawning grounds in the Yangtze River. This is the most important spawning ground in China, extending about 100 kilometers around E- Chong. Environmental characteristics are: high mountains on both banks, river fairly narrow and

water current very rapid; depth generally above 30 meters; bottom is entirely rocky with many deep pools along the way, some reach over 80 meters.

Within the stretch of spawning zone, the areas of spawning concentration are not constant. They chance according to changing water conditions.

Chen Tsun Sau (1935) lists 6 conditions that are conducive to successful spawning:

(1) spawning act occurs after 12 hours of rising water, with a water level differential of 1-2.67 m;

(2) water temperature, 26-30 C;

(3) water velocity, 1.11-1.85 m per second;

(4) there should be a long stretch of rocky rapids upstream, and better at the junction of two branches;

(5) bottom composed of sand and gravel, not mud;

(6) water contains mud and sand, showing yellowish turbidity.

Others who have surveyed the spawning of the white bighead in the West River consider the following conditions necessary for spawning:

(1) a sudden torrential rain, followed by clear sky or drizzling;

(2) water temperature, 25-30 C;

(3) water level rapidly rises over 1.5 m within a day, then levels off;

(4) water yellowish red, with a visibility of 10-15 cm;

(5) velocity, 0.67-2.22 m per second;

In the E-Chong spawning area, water conditions are generally similar to those listed above.

2. According to the survey by the Kwangtung Fishery Experimental Station, the principal natural conditions in the spawning grounds on the West River are as follows:

(1) generally at the junction of two rivers;

(2) water velocity, 0.69-2.2 m per second

(3) sudden rise of water level over 1m;

(4) a freshet after a downpour;

(5) concentrated spawning by grass carp and white bighead occurs before darkness, either right after a rain squall or after a sudden rise of water;

(6) water level drops from 11.15 m upstream to 5.0-7.5 m downstream;

(7) Sechi disc reading vary from 0.8-12 cm.

In short, a recent survey indicates that there are certain water conditions that are common to all spawning grounds:

(1) water temperature range, 20-30 C (lowest, 18.3 C);

(2) water velocity, 0.69-2.26 m per second (lowest, 0.67 m);

(3) sudden rise of water level, continuing for 12 hours, or as long as 3 to 5 days, or even 10 days. Big rise may reach 0.75 to 1 m in 12 hours; small rise, 1-1.3 m in 3 to 5 days;

(4) bottom consists of sand and gravel;

(5) water generally quite turbid, containing much sand;

(6) spawning grounds situated generally below confluence of two branch rivers;

(7) spawning occurs often after downpour and freshet.

Since 1959, the Fisheries Research Institute of Academia Sinica has been making detailed studies of the spawning of the four domestic cyprinid species and found that required conditions for spawning were not as strict as those described above.

## Spawning Requirements and Condition of Prespawning Fish

1. General conditions during spawning period. During the spawning season, even when water temperature reaches the desired range, fish do not spawn every day. Spawning is closely related to water conditions and climatic conditions. After the initial spawning, there is generally a pause for several days. Then it is followed by successive waves of spawning either by the original fish or by a new group of fish.

E-Chong fishermen point out that there are two types of spawning. One is surface spawning and the other, underwater spawning. In the black Chinese roach and striped bighead, there is only surface spawning but no underwater spawning. In other species, the type of spawning often depends upon water conditions. If the river rises gradually, underwater spawning usually prevails. But if the water level

surpasses the previous high or when there is a freshet, then surface spawning occurs.

2. Required water and climatic conditions for spawning. During the spawning season in 1953 and 1954, the Fisheries Research Institute of Academia Sinica made daily observations on water level, velocity, temperature, and turbidity in order to determine the effect of water conditions on surface spawning. In 1953 velocity was determined near the shore, and the values were much smaller than those obtained in 1954, when the determination was made in midstream. Therefore, any correlation between surface spawning and water velocity should be based on 1954 values.

These observations substantiated what fishermen have maintained and that is that surface spawning can be caused solely by a rise of water level that surpasses the previous peak, or solely be a freshet after a heavy rain. If these two conditions coincide, then surface spawning becomes especially active.

It can be seen from Table 1 that when surface spawning follows water level rise, the magnitude of the rise over the previous day was at least 0.4m (1.6 ft.) (May 15, 1954) and a maximum of 1.4m (f.6 ft.) (May 26, 1953).

Survey results in 1957 indicate that in that year the most successful spawning took place between May 19 to 26. During this period, the minimum rise of water level was 0.52 m, and the maximum, 0.83 m. On May 21, there was heavy rain, followed by huge freshet from the mountains. There was

spawning from 21 to 24, with the heaviest spawning occurring on 22. It appears that the most effective spawning is not induced solely by water level rise, but also by heavy rain.

During surface spawning, midstream velocity in 1954 was a minimum of 1.86 m per second, and a maximum of 2.26 m per second. Water temperature during 1953 and 1954 spawning season ranged from 18.3 to 23.5 C. Water transparency in 1954 was 6.16 cm.

During 1957 spawning season, dissolved oxygen was 7.43-10.13 ml/L, pH, 7.8-8.0.

The water and climatic conditions discussed above are those that are desired but not necessarily required for spawning of the four domestic cyprinid species. This is borne out by the fact that spawning also takes place in the lower part of Yangtze River. Furthermore, the conditions discussed are related to surface spawning only, and surface spawning is only one of the spawning methods. Therefore, we cannot say that if water conditions are not conducive to surface spawning, there can be no spawning at all. This is substantiated by the results of survey made by the Fisheries Institute in 1959.

3. Spawning time. At the E-Chong spawning grounds in the Yangtze River, the earliest spawner (late April) is Elopichthys bambusa: next are the white bighead and grass carp (starting late April); still next are black Chinese roach and striped bighead (late May); and the latest spawners

are Parabramis pekinensis and Barbus. In southern China (Pearl River), spawning starts in mid April, reaches its peak in May and June, and diminishes in July. In northern China, spawning is later; generally occurring in late June, when the water temperature reaches 20-23 C. Data from several years results indicate that spawning in the south is about two months ahead of that in the north.

4. Size and age composition. In the samples of spawning white bighead from E-Chong, over 60% of the fish weigh 10-13 pounds, and are primarily 5-6 years old. In Pearl River samples, over 80% weigh about 3 pounds and are 3-5 years old. In Heilung River, North China, female white bighead mature at 7 years of age, and males, at 5. It is obvious that maturity of the white bighead varies greatly according to climatic conditions and environment. Generally speaking, cultured species in southern China mature at a younger age and smaller size; those in Central and northern China mature at an older age and larger size (Table 2 and 3). In the Yangtze River area, other cultured species (grass carp, black Chinese roach, striped bighead) are even larger when mature. For example, striped bighead reach 9 kg, and grass carp, 18 kg.

5. Sex differentiation. Mature black Chinese roach and grass carp show secondary sexual characteristics during spawning season. The most prominent character is on pectoral fins. In male roach, on the dorsal side of pectoral

fins, in the first 3, 4, to a dozen fin rays, there are densely placed minute whitish granules. In female roach, these are entirely absent.

In grass carp, both sexes have granules, but they can be distinguished by the fact that granules in the males spread along the entire length of the fin rays, whereas in the females, they occur only in the distal half of the rays, and are also much narrower.

These granules appear only during the spawning season. They are superficial in nature and will easily drop off upon touch. After the spawning season, they disappear.

The secondary sexual characteristics in the white and striped bighead are also manifested on pectoral fins. In the male white bighead, there is a row of fine tooth comb along each of the several front fin rays; in the female, these fine teeth are present only on distal half of the fin rays. In the striped bighead, the male pectoral fins grow a bony sharp edge along the dorsal surface of several front rays. In the female it is entirely absent.

The secondary sexual characteristics in the bigheads are formed long before maturity, and once formed, they last throughout life.

6. Sex composition. In spawning populations of grass carp and white bighead, males always predominate in number. In white bighead, females amount to only 2.8-12% (Table 4).

In grass carp, females account for 20-25%. This, of course, does not represent the true sex ratio in natural population, where the ratio is close to 1 : 1. From the small size of vestigial eggs that are left in the body cavity after spawning (0.24 mm), it is obvious that females can spawn only once or twice a year, but males can mate continuously for many times.

7. Fecundity. Fecundity increases with the increase in age and body weight (Table 6). Fecundity differs also according to locality. For instance, fecundity of bigheads in southern China is higher than that in Yangtze River. Also, the cultured white bighead has a higher fecundity than wild fish. In the former, mature ovaries weigh as much as 17-20% of body weight; in the latter, only 12-17%.

8. Fish activity during spawning. During surface spawning, males actively chase after females, often bumping their head against the belly of the females. They move fast and sometimes leap out of water. Sometimes both sexes are seen swimming on their backs, with their pectoral fins violently trembling.

Surface spawning may occur during any time of the day or night and whether rain or shine. It lasts from many minutes to a couple of days. During low water, surfacing occurs at mid-stream; but when the water is high and current rapid, it takes place near the shore.

Males caught during surfacing act are running ripe, but females are not. It will take a few hours to a couple of days before loose eggs will run out.

9. Condition of ovaries after spawning. From the examination of ovaries of recently spawned females, two possibilities exist. In some fishes, the ovaries are very much reduced, and the residual eggs are only minute, transparent oocytes. These fish certainly will not spawn again during the same year. In some other fish, however, there remain a large number of yolk-laden large eggs, and it is entirely possible that they would spawn again.

Results of Fisheries Research Institute's study (1959) indicate that in the Yangtze River, the white bighead is a multiple spawner; but in pond cultured white bighead in Canton, southern China, spawning takes place only once a year. Further study is needed to determine whether the different types of spawning within the same species is due to environmental differences.

10. Sexual cycles. A study of Yangtze River white bighead revealed that ovary state I is present in first year fish; only a few individuals of second year fish still contain stage I ovary. In fish above age I that weight from 1-4 kg, ovaries are usually in stage II. Fish that mature the succeeding year have stage III ovaries toward the end of autumn, but stage IV ovaries entering into winter. From spring until May before spawning, ovaries are usually in

stage IV, but they shortly transform into stage V. After spawning, ovaries enter into stage IV. Undeposited oocytes become degenerated and absorbed, and after some time, they revert to stage III.

Our preliminary conclusion is that the same species of fish may overwinter with a different ovary stage under different geographical conditions.

11. Spawning habitat. All the four domestic cyprinids migrate upstream to spawn. It is generally known that they start to migrate just before spawning season. However, according to some fishermen, a good portion of fish migrate upstream during the previous fall into the spawning ground and overwinter in deep water, and come out to spawn when spring comes. A tagging study is required to solve this question.

## Natural Breeding of the Carp

Carp is widely distributed in China. Because its demand on environmental factors for development of its sex glands is not as strict as that of grass carp and others, carp breeds naturally in flowing as well as still water all over China.

1. Spawning conditions. Carp start to spawn in March or April in Yangtze River, in late December in Pear River, in April-May in Yellow River and North China, and in June in Amur River area. Although spawning season differs so much from locality to locality, water temperature at which

spawning starts is fairly uniform; namely, at 17-18 C. Even within the same river, spawning time varies according to water temperature. In smaller, shallower bodies of water, where temperature rises rapidly due to sunshine, spawning usually starts earlier than in larger, deeper waters.

Spawning usually lasts about two months. In some areas, according to local fishermen, carp may spawn twice a year: once in the spring, and another time in the fall.

Still to slow flowing water, from 3.3-6.6 feet deep, with submerged vegetation is the fundamental requirement for carp spawning. In streams, spawning takes place in shallow pools or slow-flowing areas. During flooding time, areas near both banks and submerged terrestrial plants become good spawning grounds. In lakes, carp prefer shoal areas where there is some aquatic vegetation. However, carp will avoid areas where plants are too thick to allow for free movement.

Large amounts of water which follow flood conditions are stimulating to carp spawning. The current attracts parent fish to migrate upstream and the spawn in nearby shallow areas. Aside from attracting fish, current flow apparently hastens the development of ovary from stage IV to V.

Spawning is usually active after a spring rain when water temperature rises to above 17 C. Peak spawning takes place between 18-21 C. Spawning has also been observed in water at 26 C. When the weather suddenly

changes, especially due to wind and lower water temperature, spawning will abruptly come to a stop.

The most active spawning takes place from midnight to dawn. Sometimes it may start in the evening and continues until noon the next day. Spawning seldom takes place in the afternoon.

2. Spawning act. Two or three male carp chase after one female. When the female is approaching aquatic plants, the male will nudge against the female belly with his snort. Instantly the female body shivers violently and she shoots her eggs onto the vegetation. Simultaneously the males eject milt. In one deposition, only a small number of eggs are laid. Therefore, it takes repeated deposition to finish spawning. Upon contact with vegetation the eggs become attached; if not, they settle down on the bottom.

3. Age at maturity. In early spring, males that are 20 cm long, weighing 250 g, and are one-winter fish, are already running ripe. Females of the same age attain a body length of 24 cm and a weight of 380 g. Only a few of these will mature during the year. Nearly all 2-winter females, 40 cm long and 1500 g in weight, will mature and spawn.

4. Fecundity. In 3-winter fish, measuring 44-48 cm long and 1.9-2.75 kg, there are 244,000 eggs on the average. 5-winter fish, 54 cm long and 3.5 kg in wieght, contain 447,000 eggs. 6-winter fish, 63 cm long and weighing 5.7 kg, contain 973,000 eggs.

## Fertilization and Development

1. Mature sex cells. The eggs of grass carp, black Chinese roach, white bighead, striped bighead, and bream are planktonic. Their common characteristics are (1) Non-adhesive; (2) after deposition, the egg absorbs a large amount of water increasing its buoyancy. Because of this even though the density of the eggs is a little larger than that of water, they can maintain a submerged condition in flowing water. The eggs of carp, on the other hand, are adhesive, and are orange and transparent.

Upon contact with water, the eggs lose their fertilization potential within a short time. In natural spawning, egg and milt deposition occur simultaneously.

(1) Mature eggs. The normal mature eggs of grass carp, black Chinese roach, white bighead, and striped bighead have a pleasing greenish coloration. They are entirely spherical and are adhesive, between 1.5 and 1.8 mm in diameter.

In naturally spawning grass carp and bigheads, there may be over-ripened eggs. In artificially induced maturity, there are often immature, over-ripe, dead, degenerated and even empty eggs. Good quality eggs are generally shiny, strongly water absorbent, and quite elastic. Fertilization rates for this kind of eggs are very high. Over-ripe eggs lack luster, often appear grayish white, and are not very adhesive. In extreme cases, they are irregular in shape, wrinkled, and devoid of elasticity. They cannot absorb

water. The fertilization rate of over-ripe eggs is very low; their cell division is irregular and results in abnormal embryos.

Immature eggs are much smaller; their nuclei are not polarized, and nuclear membrane not disintegrated. Females can be induced to deposit immature eggs.

Dead eggs can be told by their opague appearance. Sometimes they have no contents inside.

(2) Mature spermatozoa. A sperm can be distinctly separated into head, neck, and tail piece. Live spermatozoa are very motile. In the bighead, one ml of milt contains 48 million spermatozoa. Under 25-28 C, sperm remain viable in normal saline for 20-25 minutes. If no saline solution is added, sperm can still move, but at a slower rate. It has been found that the faster spermatozoa swim, the sooner they will die. We found that under 2-6 C, spermatozoa of white bighead will remain viable for 264 hours. However, as time passes, they will become more and more sluggish.

2. Changes of fertilized eggs. The first change of fertilized eggs is the clear differentiation of animal and vegetative poles. Within a very short time, a bulging germinal disc is formed at the animal pole. Due to absorption of water, the egg membrane and vitelline membrane become separated, creating an interspace between them - a perivitteline space. This process continues for 2-3 hours after fertilization. The eventual size of the eggs may reach 5.5-6.0 mm in diameter.

Carp eggs can attain only 1.4-1.8 mm after water absorption, and the diameter of yolk is about 1.2 mm. Their perivitteline space is also much smaller than that of ther cyprinids.

It must be pointed out that unfertilized eggs will undergo the same changes as described above. Therefore, the formation of germinal disc and perivitteline space, and the enlargement of egg membrane cannot be taken as a definite sign of fertilization. However, unfertilized eggs will undergo no further development after the formation of germinal disc but will rapidly die. Also, yolk will gradually become opague and finally decay and disintegrate.

In 4 ml of mature eggs without water, there are 2,453 in number. After water absorption, there are only 48 eggs in 4 ml. Water hardened eggs possess high elasticity; they often slip away under the touch of a dissecting needle and will not break by a drop from table to floor. Obviously this high elasticity has a highly protective function. When drifting in a turbulent water, the eggs can avoid suffering damages.

3. Development of the Embryo.

(1) Cleavages. Cleavage of the cultured cyprinids is of the typical discoidal type. Cell division takes place only in the animal pole. The many small cells are arranged in a single plane above the undivided yolk.

(2) Blastula. Cells migrate to form a multilayered outer wall, enclosing an empty space in the center.

(3) Gastrula. Many experiments have proved that the gastrula stage of white bighead and striped bighead is most sensitive to environmental changes. Mass mortality often occurs during the formation of gastrula. We therefore regard the gastrula stage as the critical period during the development of the embryo, and care must be taken to avoid severe changes of environmental factors.

(4) Hatching. In the embryo of white bighead, neural plate and optic lobes become distinguishable 10 hours and 50 minutes after fertilization in 25-27.9 C water; after 12 hours and 45 minutes, 12 myomeres appear; after 14 hours and 35 minutes, autidory sacs and olfactory lobes appear and myomeres increase to 20, yolk becomes lengthened, and notochord becomes distinct; after 17 hours and 30 minutes, myomeres can slightly contract; after 18 hours and 31 minutes to 22 hours and 45 minutes, the heart starts to beat, blood starts to circulate, and the embryo can move inside the egg. Hatching enzyme is secreted from under the head to soften egg membrane. This is followed by violent vibration of the tail and the head will erupt the egg membrane and emerge.

(5) Rate of development. Table 8 shows some random experiments on time sequence of various developmental stages.

According to report from West River, grass carp from there hatch 32-40 hours after fertilization in 21-26 C. Egg diameter is 1.5-2.1 mm, and increases to 4.9-5.0 mm after water hardening.

Fertilized eggs of black Chinese roach increase in size by 7-fold after water absorption. Under 24-25 C, hatching takes place after 24.5 hours. Under 19.0-20.5 C, it takes 35 hours and 52 minutes.

Fertilized eggs of white bighead from I-Chong have a yolk 1.3-1.4 mm in diameter. After water absorption, egg diameter increases to 5.5-6.0 mm. In 22 C, the embryo hatches in 44 hours. Newly hatched larvae measure 6.3-6.5 mm in total length. In West River, white bighead egg yolk is 1 mm in diameter, and the egg diameter increases by 4-fold after water hardening. In 24-27 C, hatching takes 17 hours. In Kwangtung where maturation is induced, the egg diameter is 1.4 mm, and increases to 5.9 mm after water hardening. In 25-27.9 C, hatching takes place in 24 hours and 25 minutes.

Fertilized eggs of the bream from West River have yolk that is 0.7 mm in diameter. They have thick egg membrane and are transparent. Upon water hardening, egg diameter increases by 4-fold. At 26 C, hatching takes 18 hours.

The time required for the hatching of black Chine Se roach and white bighead differs considerably from West River to I-Chong. The difference is greater than would be expected from temperature difference alone. Besides, the hatching time of grass carp is shorter in I-Chong where water temperature is lower than in West River. It seems clear that water temperature is not the only factor that affects the rate of hatching.

Research by Kwangtung Fisheries Research Institute shows that the development rate of the same species of fish in the same area is directly proportional to water temperature

| Mean water temperature | 20 | 22 | 23 | 24 | 25 | 26 | 26.5 | 27 | 29.5 | 30 | 30.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hatching hours | 50 | 38 | 33 | 31 | 24 | 21 | 20 | 19.5 | 17 | 16 | 15.5 |

In individual experiments, normal development is achieved in water temperatures as low as 18 C and as high as 31 C. In 15 C, development is much delayed and embryos are deformed, such as a crooked body and enlarged pericardium, sometimes resulting in total mortality. At 34-37 C, all embryos suffer death.

4. Post-embryonic development. The post-embryonic development of grass carp, white bighead and carp can be summarized as follows:

Newly hatched larvae of grass carp and white bighead are 5.2-5.7 mm in TL, transparent, having 36-40 myomeres. Yolk sac is pear shaped, occupying the major part of the belly. Olfactory and auditory sacs are distinct. Dorsal finfold is contiguous with caudal finfold. tail length is slightly less than 1/2 of body length. Ventral finfold is divided into preanal and postanal portions. Pectoral and pelvic fins not yet formed. Pigments entirely lacking, blood slightly pinkish, intestine not opened. Larvae cannot swim, but can move vertically by vibrating tail. Carp larvae have 42 myomeres; their head

part has a minute adhesive organ. Two days after hatching, they hang still onto surface plants or container wall.

Table 1. Water and weather conditions at E-Chong spawning ground in 1953 and 1954.

| Year | 1953 | | | | | 1954 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of spawning: | 26/4 | 4/5 | 20/5 | 21/5 | 22/5 | 26/5 | 27/4 | 6/5 | 9/5 | 15/5 | 20/5 |
| Water level (m): | 44.74 | 43.82 | 43.46 | 43.21 | 32.27 | 44.94 | 43.60 | 43.64 | 44.90 | 45.08 | 45 |
| Difference from previous day: | -0.66 | -0.35 | -0.32 | -0.25 | -0.06 | -1.41 | -0.31 | 0.93 | -0.55 | -0.49 | -.1 |
| Velocity of surface flow (m/s): | 1.13 | 0.94 | 0.94 | 0.78 | 0.85 | 1.20 | 1.93 | 1.86 | 2.05 | 2.26 | 2.2 |
| Water Temp (C): | 18.3 | 21.3 | 23.5 | 23.0 | 22.5 | 22.0 | 20.0 | 21.1 | 20.8 | 20.6 | 21. |
| Date of heavy rain at E-Chong: | -- | 3/5 | 20/5 | 21/5 | 21/5 | -- | 26/4 | 5/5 | 8/5 | -- | 19/5 |

Table 2 Comparison of size composition of spawning white bighead from Yangtze and Pearl rivers.

| Year and Month | River | N | Body weight, in g | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 500–1000 | 1000–2000 | 2001–3000 | 3001–4000 | 4001–5000 | 5001–6000 | 6001–7000 | 7001–8000 | 8001–9000 | 9001–10000 |
| 19 May | Yangtze | 120 | | | | 1. | 10 | 12 | 7 | 16 | 25 | 49 |
| | | % | | | | 0.3 | 8.3 | 10 | 5.8 | 13.4 | 20.9 | 40.9 |
| 1940 May–June | Pearl | 30 | 1 | 9 | 16 | 4 | | | | | | |
| | | % | 3.3 | 30 | 53.3 | 13.3 | | | | | | |

Table 53 Comparison of body length (cm) and weight (g) of female grass carp and white bighead in Yangtze, Pearl, and Sungari rivers.

| Year and Month | River | White bighead | | | | | | Grass carp | | | | | | Data by |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Large | | Small | | Medium | | Large | | Small | | Medium | | |
| | | L | Wt | L | Wt | L | Wt | L | Wt | L | Wt | L | Wt | |
| 1957 May | Yang-tze | 100 | 12000 | 75 | 7500 | 97 | 9500 | -- | 16500 | -- | 7000 | -- | 11000 | Academia Sinica |
| 1940 M-J | West | 57 | 2833 | 46 | 830 | 54 | 2000 | -- | 16000 | -- | 3500 | 67 | 5700 | Fish. Exp. Station Kwangsi Prov. |
| 1956 J-J | Sung-ari | 72 | ----- | 94 1/2 | -- | -- | 4000 | -- | 12000 | -- | 7000 | -- | 10000 | Fish. Exp. Station Harbin |

Table 4. Sex ratios of grass carp and white bighead in three localities.

| Species | Yangtze (1953) N | % M | % F | West River (1940) N | % M | % F | Sungari River (1956) N | % M | % F |
|---|---|---|---|---|---|---|---|---|---|
| White bighead | 147 | 97.2 | 2.8 | 33 | 88 | 12 | 172 | 96 | 4 |
| Grass carp | 112 | 77.7 | 22.3 | 40 | 75 | 25 | --- | 80 | 20 |

Table 5. Fecundity of four cyprinids in Yangtze River.

| Species | Body wt. (kg) | Ovary (kg) | No. of eggs |
|---|---|---|---|
| Grass carp | 14.62 | 1.60 | 960,000 |
| Black Chinese roach | 18.50 | 2.25 | 1,180,000 |
| White bighead | 10.56 | 1.04 | 800,000 |
| Striped bighead | 18.50 | 1.96 | 1,100,000 |

Table 6. Fecundity of bigheads in Kwangtung.

| Species | Body wt. (kg) | Body length (cm) | No. of eggs |
|---|---|---|---|
| White bighead | 4-5 | 60-70 | 400,000-650,000 |
| | 3.30 | 56 | 310,000 |
| | 4.53 | 66 | 580,000 |
| | 1.75 | 41 | 158,000 |
| Striped bighead | 1.75 | 84 | 1,400,000 |